RGS Focal Plane Camera (RFC) Technology and Implementation Status

George Ricker,
on behalf of the MIT Con-X RFC Team
(John Doty, Steve Kissel, Gregory Prigozhin)

Constellation X
Facility Science Team Meeting
Goddard Space Flight Center
20 November 2003

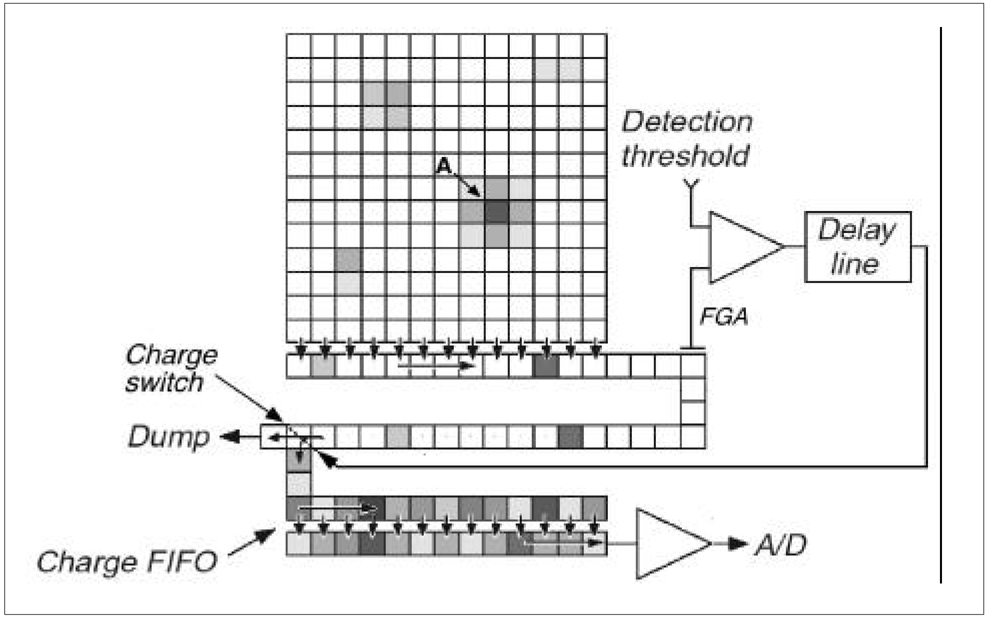
Outline

- **Review of Event Driven CCD**
- **Progress in Back-illuminated CCD Technology**
- **Implications for Extended ($E_x < 0.25$ keV) Low Energy Response**
- **Concept for an Offplane Grating Readout**

Key Technology Drivers for RFC

- High QE for 0.25 - 2 keV band
- High yield for back-illuminated CCDs
- Adequate energy resolution at low E_x
  - Grating order separation
  - Particle background rejection
- Radiation tolerant at L2
- Stable Calibration
  - Near room temperature operation
  - Pile up resistant

EDCCD: Baseline Sensor



- **System Constraints relief for Con-X**
  - Lower power dissipation at a given frame rate (>100 x less)
  - Enables integrated flight camera testing at room temperature
  - Compatible with broad operating temperature range (~ 0° C to -120 ° C)
  - Reduced shielding requirement (>10x more radhard)
  - High frame rate: relaxed S/C stability and jitter requirements

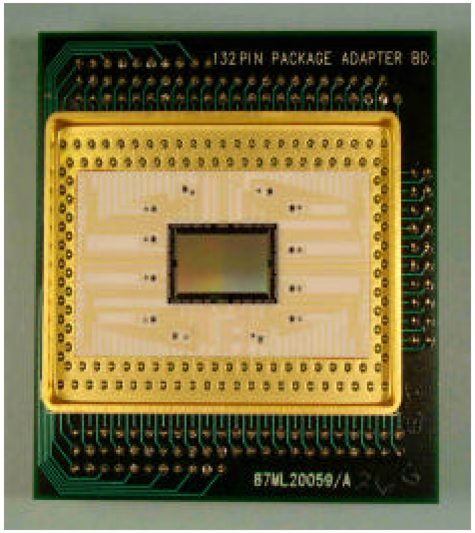
- **Event-Driven CCD: Advantages**
  - Pixels are non-destructively sensed, and only those with signal charge are saved and digitized
  - Compatible with high yield BI processes
  - High speed: 100 x Chandra/ACIS (greatly reduced pileup)

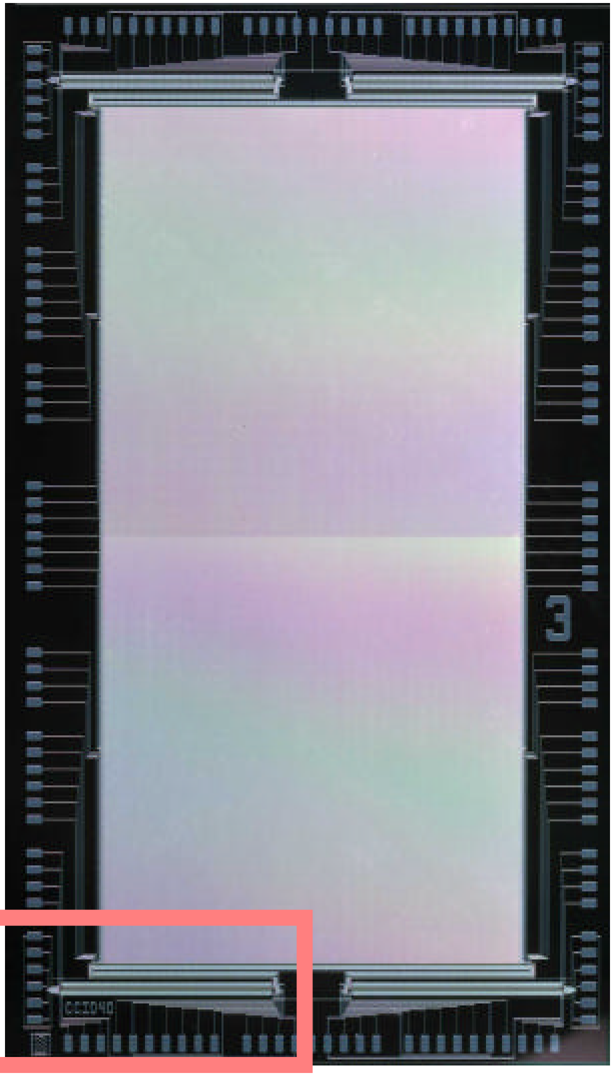
- **Additional Advantages of EDCCD**
  - Improved QE for 0.2 - 2 keV band
  - High frame rate (30-50 Hz); thus, can use thinner optical blocking filter (OBF)
  - High yields and reduced risk
    - Conventional MOS CCD processing
    - Compilation of separately-tested innovations
    - Flight-proven (ASCA, Chandra) key elements
      - Parallel register array
      - Low noise floating diffusion output amplifier

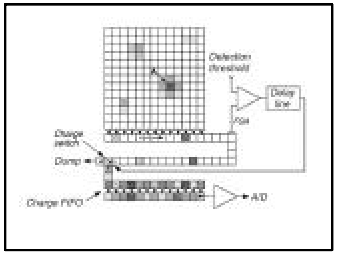
EDCCD Technology Status

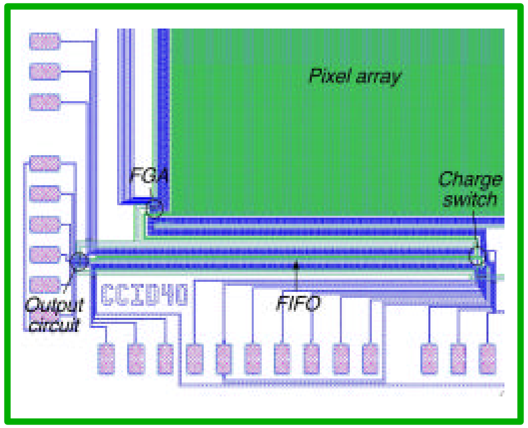
Gen 1-Lot 1 EDCCD

- *512 x 512 prototype*
- *Unthinned Device*
- *Tested Excellent Performance as "standard CCD"*
- *Special drive electronics for ED operation in test*
- *Full EDCCD mode in Dec*

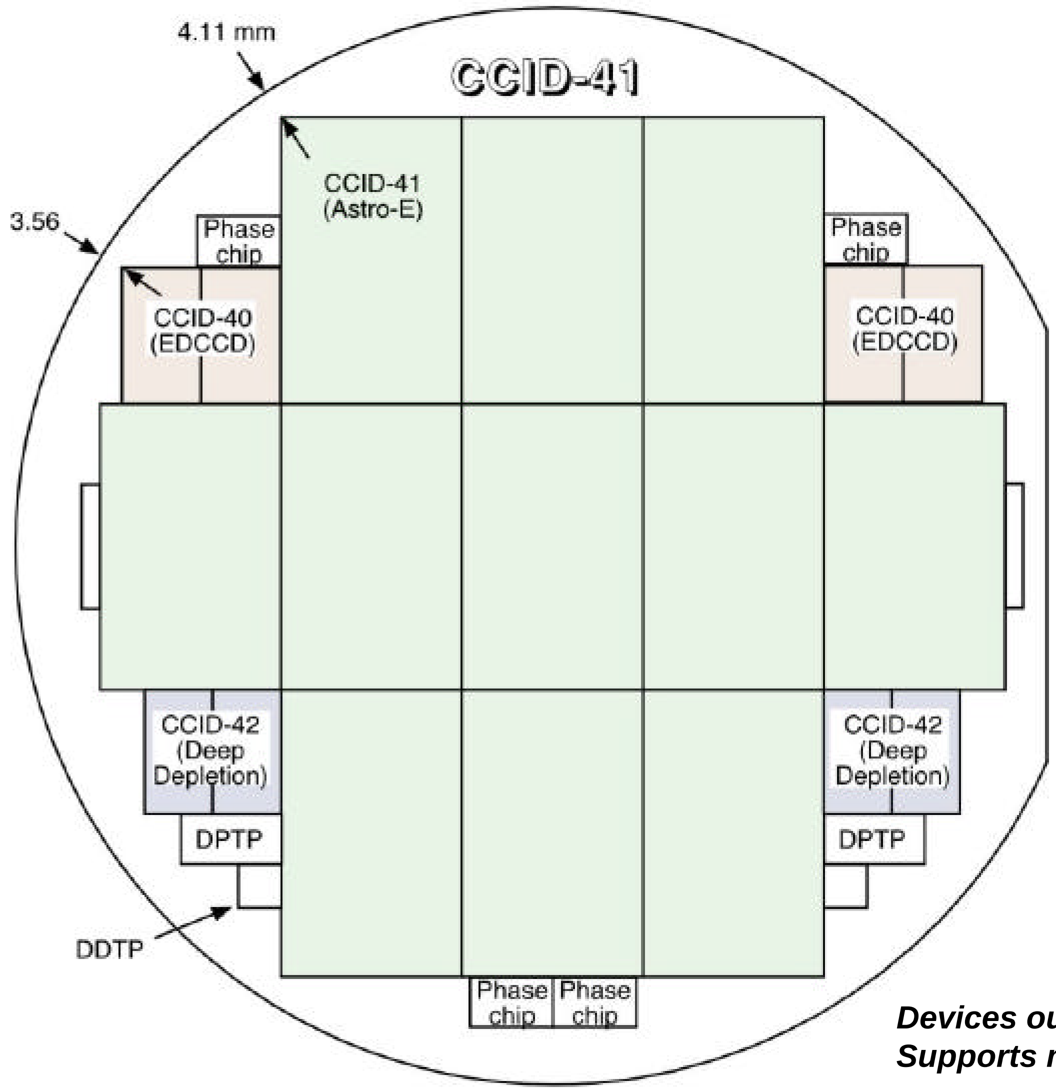








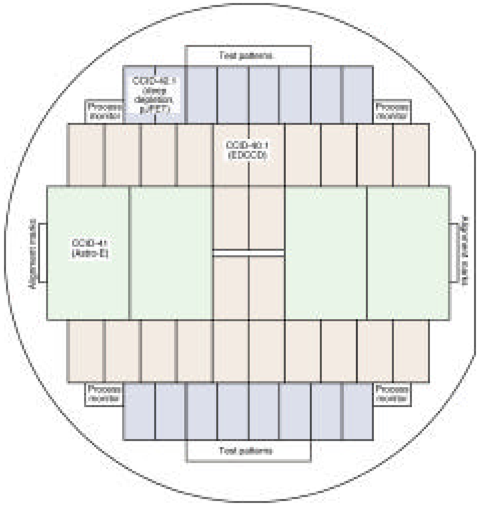
EDCCD Gen 1-Lot 2 Wafer Layout: Fab in Progress



Devices out ~1 Feb 2004
Supports many thinning and BI "splits"

EDCCD Gen 1.5 – Lot 1 Status

New wafer layout



Mechanism for improved tolerance to radiation damage

Under irradiation vacancies and interstitials are formed.

Then the following reactions producing electron traps take place:

V + V -> V–V (divacancy)

V + P -> P–V (P–V center)

V + O -> O–V (O–V center)

Diffusion of Oxygen increases its concentration by a factor of 20.

This strongly shifts equilibrium to the last reaction.

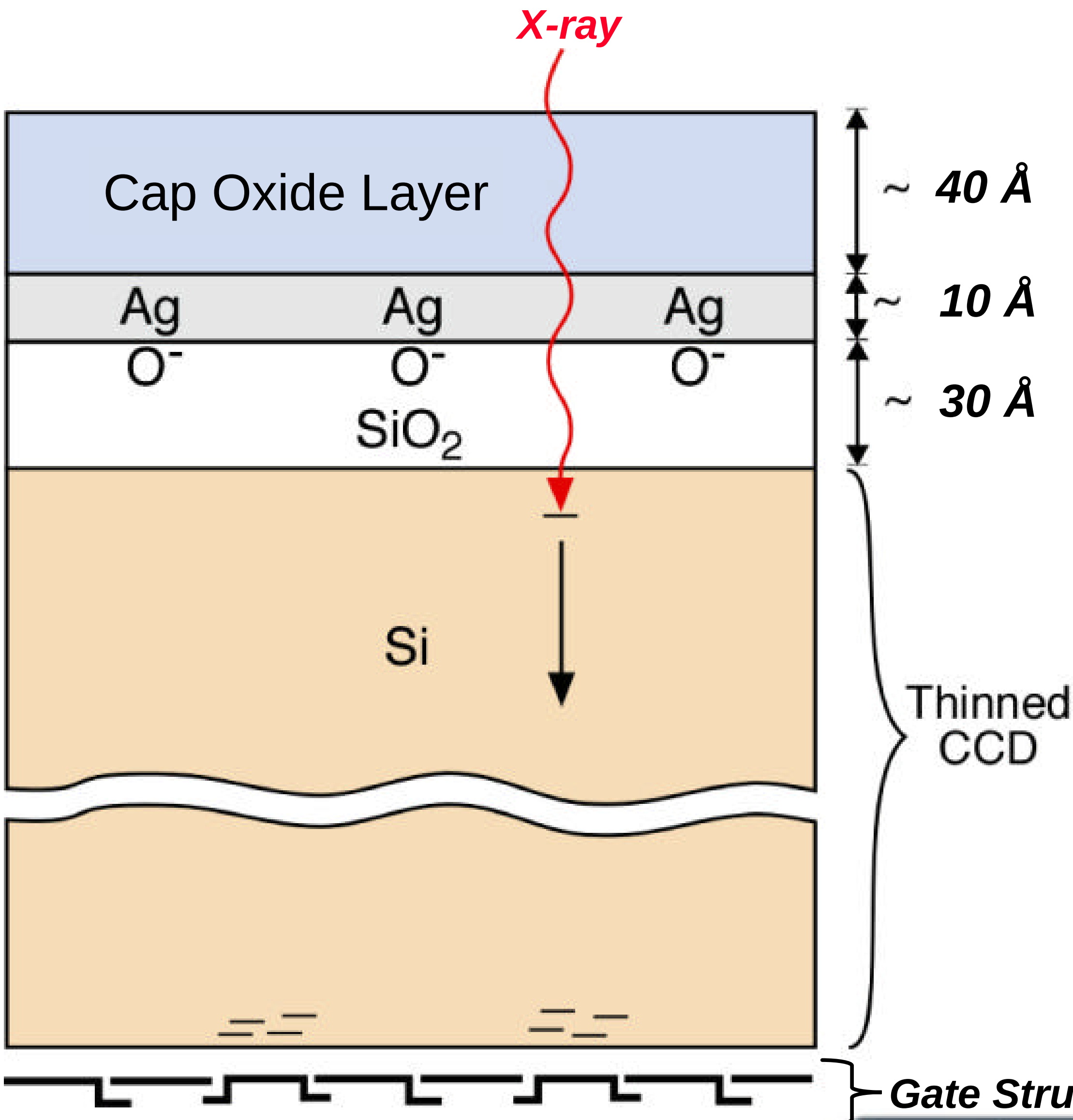
Formation of the most damaging V–V and P–V centers is suppressed.

- **Wafer layout has been determined (see figure on the right).**
- **Wafers have been selected (6 Wacker 5000 Ohm cm wafers + 6 Topsil 9000 Ohm cm wafers) and preliminary high temperature processing has been completed.**
- **Sample wafers will undergo "oxygenation" in order to improve radiation tolerance (mechanism is explained on the left).**
- **Improved output stage (for high speed readout) has been incorporated into the device. A new test structure for a very high sensitivity output (>20 μV/e^-) is being designed.**
- **Lot completion ~15 May 2004; wafers will be thinnable.**

Outline

- Review of Event Driven CCD
- **Progress in Back-illuminated CCD Technology**
- Implications for Extended (E_x < 0.25 keV) Low Energy Response
- Concept for an Offplane Grating Readout

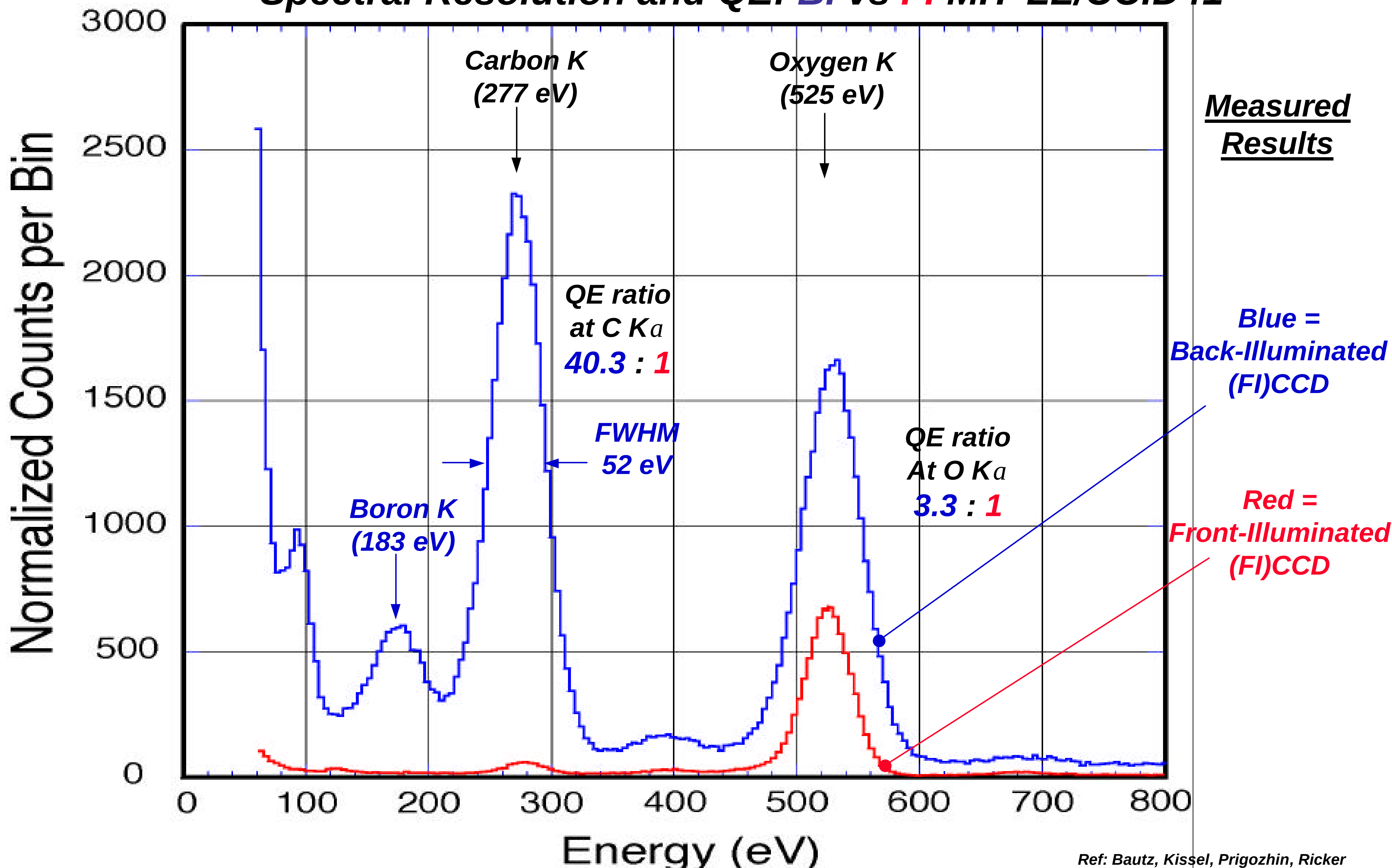
Cross Section of "Chemisorption-charged" (CC) BI CCD



Status of CC Process

- *Initial Development at U. Arizona (M. Lesser)*
- *Low temp process (130C)*
- *Relies on stable, buried layer of O^- ions for backside repulsive field*
- *Appears to be stable long term (>3 years)*
- *Advanced Development at MIT Lincoln Lab in progress*
- *Four lots fabbed thus far; high yields; excellent UV performance*
- *Reference: Burke et al 2003 IEEE Nuc Sci (in press)*

Spectral Resolution and QE: BI vs FI MIT-LL/CCID41



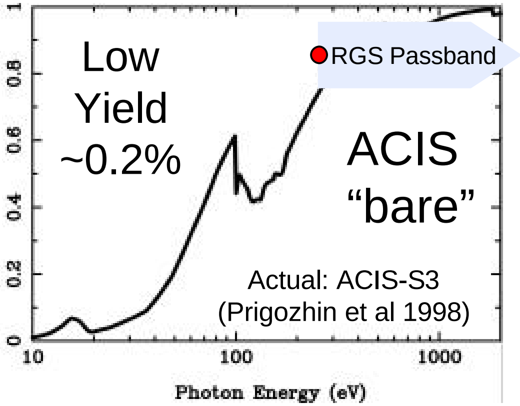
Ref: Bautz, Kissel, Prigozhin, Ricker

Outline

- Review of Event Driven CCD
- Progress in Back-illuminated CCD Technology
- Implications for Extended ($E_x < 0.25$ keV) Low Energy Response
- Concept for an Offplane Grating Readout

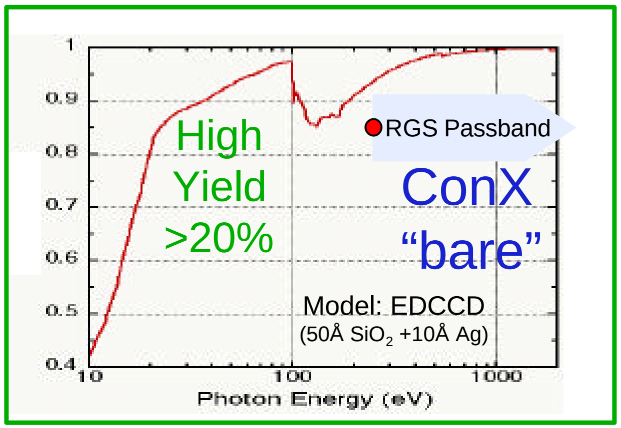
Quantum Efficiency Comparison: ACIS-S3 (BI) vs EDCCD (BI)

- Plots at left show QE of “bare CCD” ie no optical blocking filter (OBF)

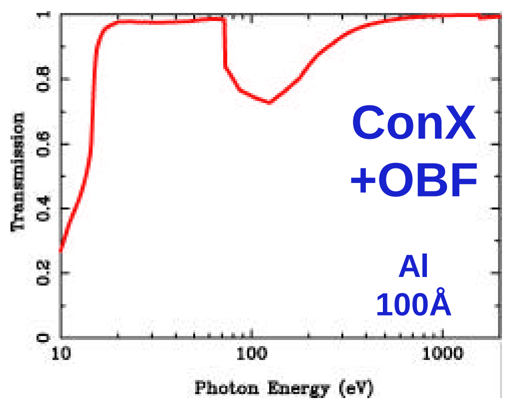


● = QE_{spec} at 0.25 keV

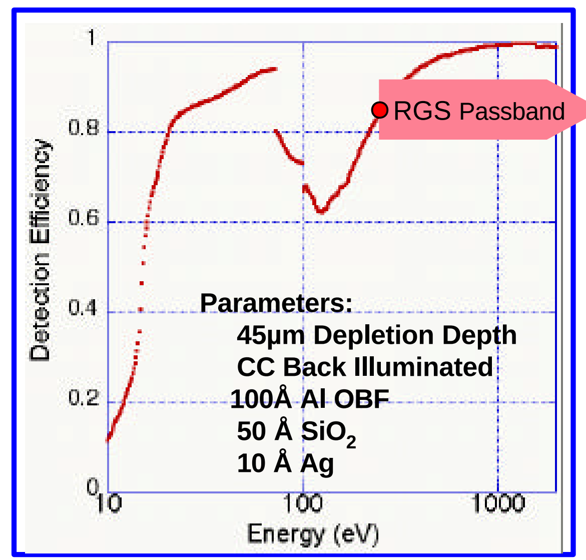
EDCCD + OBF:Predicted QE



*



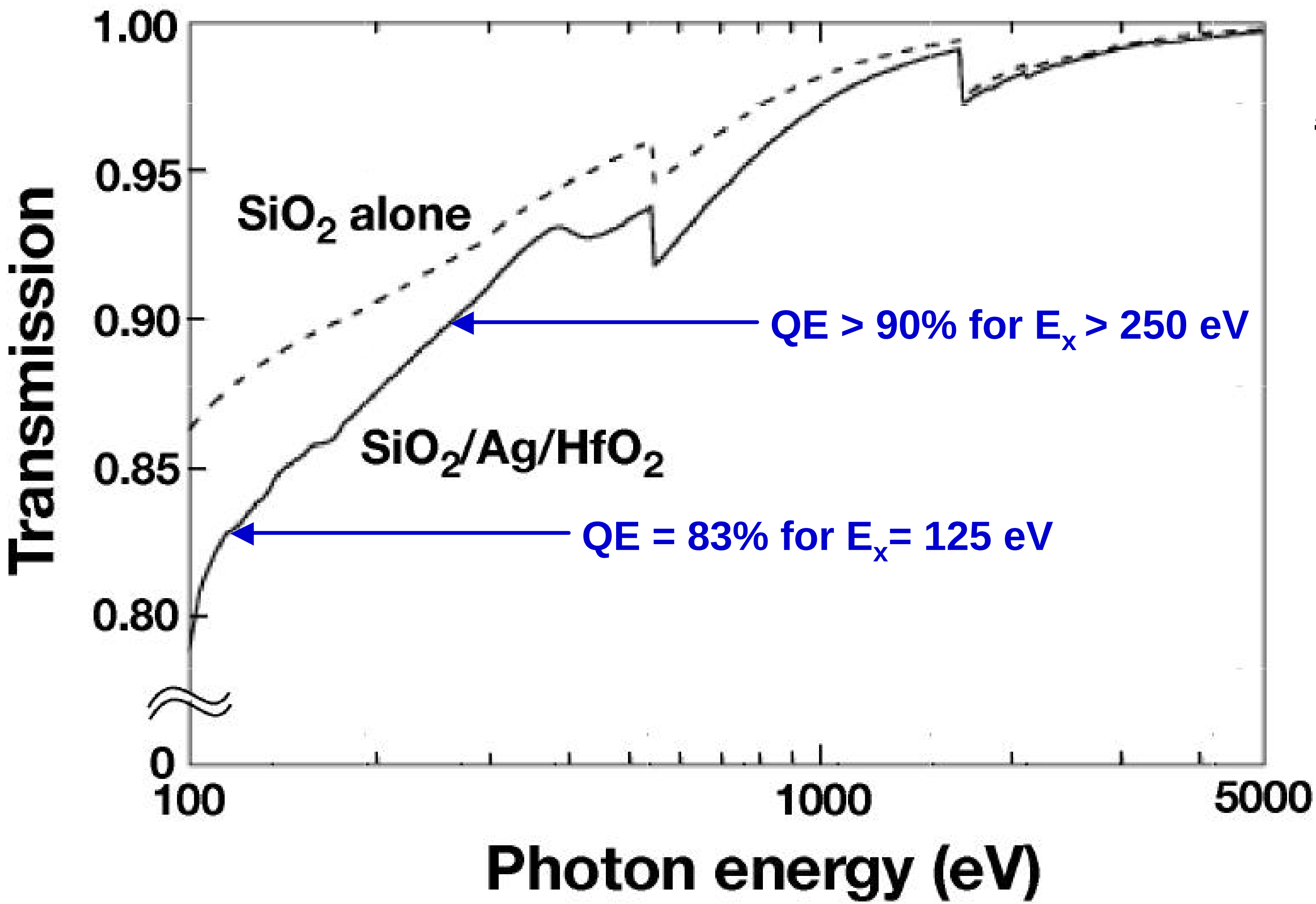
=



Conclusions:

- An EDCCD can use >10x thinner OBF than ACIS >>> higher X-ray transmission at low E_x
- Back-illuminated EDCCD should meet Con-X low energy QE specification

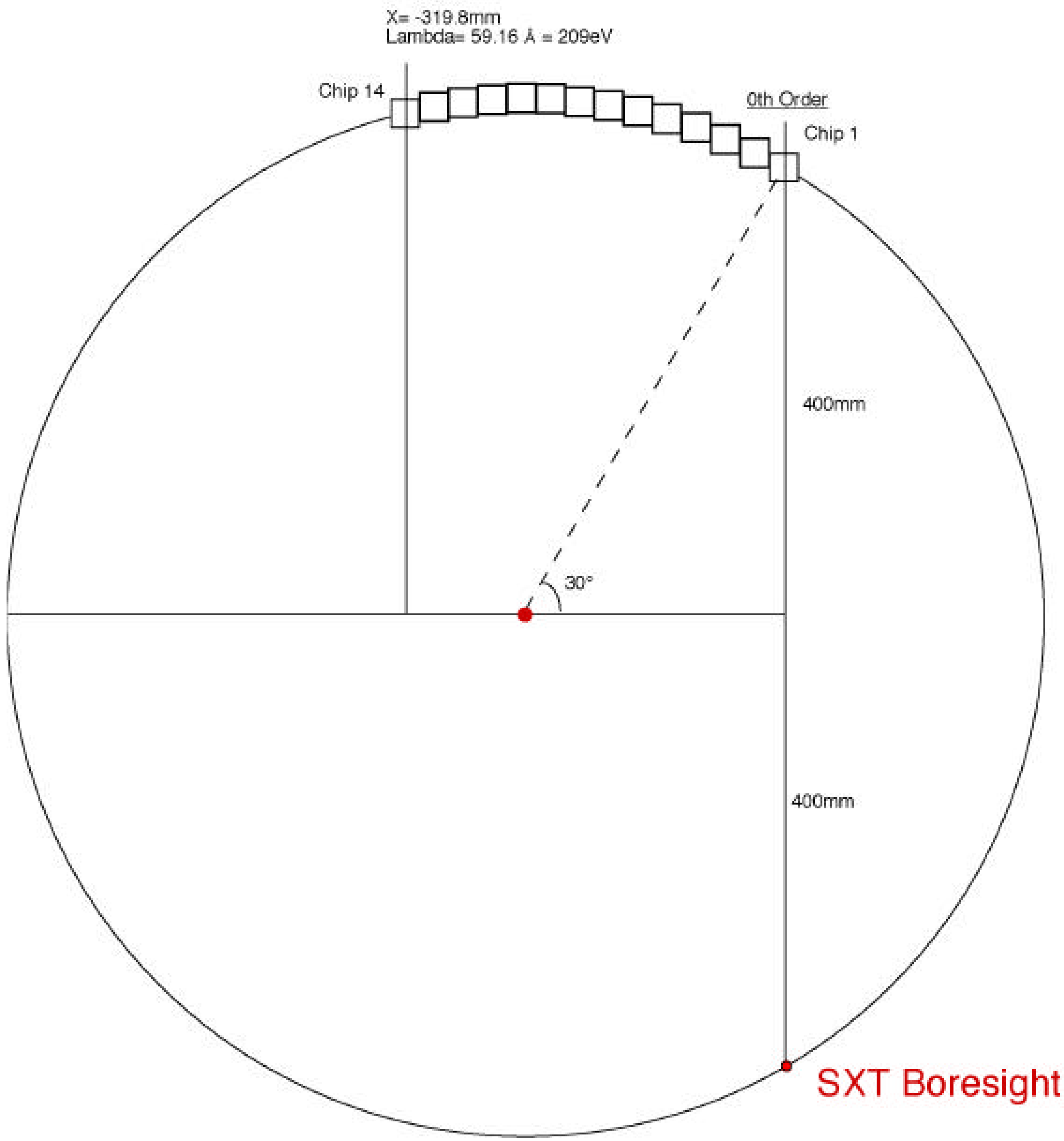
Calculated QE vs Energy for Chemisorption-charged (CC) BI CCD



No OBF

Outline

- Review of Event Driven CCD
- Progress in Back-illuminated CCD Technology
- Implications for Extended (E_x < 0.25 keV) Low Energy Response
- Concept for an Offplane Grating Readout



CCD Detector Array for Off-Plane Grating:

- 1Kx1K EDCCD
- Off Plane 5800 lp/mm
- Scale Drawing

Scales:
20.6 arcsec/mm
=0.49 arcsec/pixel
=8.4 arcmin/chip

Dispersion:
4.45 mÅ/pixel
= 0.016 eV/pixel @ 209 eV
= 0.032 eV/arcsec @ 209 eV
= 0.064 eV/(2arcsec) @ 209 eV
=>R=3300 @209eV

Near Term Development Focus for RGS Focal Plane Camera

- EDCCDs:
  - Complete Fab of Gen 1-Lot 2 (in process; devices in Feb ‘04)
  - Lot Fab for Gen 1.5-Lot1 (lot start ~15 Dec; complete in May ‘04)
  - Layout for Gen 2 EDCCD (lot start ~ 15 Mar ‘04)
  - EDCCD mode testing of Gen 1-Lot 1 packaged devices
- Continue QE measurements at E_x = 0.25 keV and below
  - CC process modelling
  - Radiation damage testing of CC devices
  - Accelerated stability testing and cycling of CC devices
- Assess camera impacts for:
  - $E_{x,\ low}$ < 0.25 keV (ie $E_{x,\ low}$= 0.125 keV would double array length)
  - Off plane design (ie crescent-shaped focal plane)